JAIPUR ENGINEERING COLLEGE AND RESEARCH CENTRE

Year & Sem - IV Year & VII Semester
Subject - Power Generation Sources [7EE6-60.2]
Unit/Topic - IV / Wind Energy (Part -1)
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VISSION AND MISSION OF INSTITUTE

Vision:

To become a renowned center of outcome based learning, and work towards academic, professional, cultural and social enrichment of the lives of individuals and communities.

Mission:

M1: Focus on evaluation of learning outcomes and motivate students to inculcate research aptitude by project based learning.

M2: Identify, based on informed perception of Indian, regional and global needs, areas of focus and provide platform to gain knowledge and solutions.

M3: Offer opportunities for interaction between academia and industry.

M4: Develop human potential to its fullest extent so that intellectually capable and imaginatively gifted leaders can emerge in a range of professions.

VISSION AND MISSION OF DEPARTMENT

Vision:

The Mechanical Engineering Department strives to be recognized globally for excellent technical knowledge and to produce quality human resource, which can manage the advance technologies and contribute to society through entrepreneurship and leadership.

Mission:

M1: To impart highest quality technical knowledge to the learners to make them globally competitive mechanical engineers.

M2: To provide the learners ethical guidelines along with excellent academic environment for a long productive career.

M3: To promote industry-institute linkage.

POWER AND ENERGY IN THE WIND

It is well known that wind is certainly an inexhaustible abundant source of energy which is caused by the differential solar radiation on the Earth's geo-diverse surfaces, having different degrees of absorption/ reflection/ refraction/ convection/ transmission.

Wind power is not only a renewable green source of energy; but also results in significant saving of potable/drinking water, which is much needed for human survival. Electricity generation by wind consumes only $(1/200)^{th}$ to $(1/400)^{th}$ of water that is used by nuclear/oil/coal.

We understand the wind as breeze (gentle/comfortable), a force to reckon with at times of design of structures, a power to harness through wind machines and a brute force/power to be resisted during cyclones/hurricanes. We need to be clear that a Country with a long coast line need not necessarily be having economic/technical potential for wind power with its diurnal variations of land breeze/sea breeze.

At the other extreme the mere occurrence of good monsoon or frequency of cyclones & hurricanes may not provide an economical viability, a technical feasibility of wind power. When wind (i.e. velocity 'U') is a resource, it has a force proportional to square of wind velocity (U^2), the power proportional to cube of wind velocity (U^3).

HOW IT WORKS

Wind is a form of Solar energy

Wind is caused by the uneven heating of the earth's surface and rotation of the Earth

Wind Turbines convert the kinetic energy in the wind to mechanical power

A generator can convert the mechanical power into electricity

A wind turbine works the opposite of a fan

The wind turns the blades, which spin a shaft

Which connects to a generator and makes electricity

Potential of Wind Energy in India

State wise wind power capacity (MW) [16,17,and18]].

S. No	State	2014 (MW)	2015 (MW)	2016 (MW)	2017 (MW)	% Share 2017	Tentative by 2020
1.	Tamil Nadu	7276	7515	7694	7970	24.2	11,900
2.	Maharashtra	4098	4638	4666	4778	14.5	7600
3.	Gujarat	3414	3877	4441	5537	16.8	8800
4.	Rajasthan	2820	3866	4217	4282	13.0	8600
5	Karnataka	2409	2872	3154	3793	11.5	6200
6	Andhra Pradesh	753	1155	2092	3835	11.6	8100
7	Madhya Pradesh	439	1126	2288	2498	7.6	6200
8	Kerala	55	35	43	51	0.15	–
9	Telangana	-	–	99	101	0.31	2000
10	Others	-	4	4.30	4.30	0.013	600
Total		**21,264**	**25,088**	**28,700**	**32,848**	**100**	**60000**

Global scenario of wind energy [2017]

Top 10 countries cumulative installed capacity 2011–2017 [5–8].

S. No.	Top 10 Country	MW (2011)	MW (2012)	MW (2013)	MW (2014)	MW (2015)	MW (2016)	MW (2017)	% Share
1	PR China	62,364	75,324	91,412	114,609	145,362	168,690	188,232	35
2	USA	46,919	60,007	61,091	65,879	74,471	82,184	89,077	17
3	Germany	29,060	31,308	34,250	39,165	44,947	50,018	56,132	10
4	India[c]	16,084	18,421	20,150	22,465	25,088	28,700	32,848	6
5	Spain	21,674	22,796	22,959	22,987	23,025	23,074	23,170	4
6	UK	6540	8445	10,531	12,400	13,603	14,543	18,872	3
7	Canada[e]	5265	6200	7803	9694	11,205	11,900	12,239	2
8	France	6800	7564	8254	9285	10,358	10,740	13,759	3
9	Italy[ab]	6737	8144	8552	8663	8958	9257	9479	2
10	Brazil[d]	1431	2508	3466	5939	8715	10,740	12,763	2

[a] Rank 6 up to year 2011.
[b] Rank 7 up to 2013.
[c] Rank 5 up to year 2014.
[d] Rank 8 by the end of 2017.
[e] Rank 9 by the end of 2017.

ISSUES IN HARNESSING WIND POTENTIAL

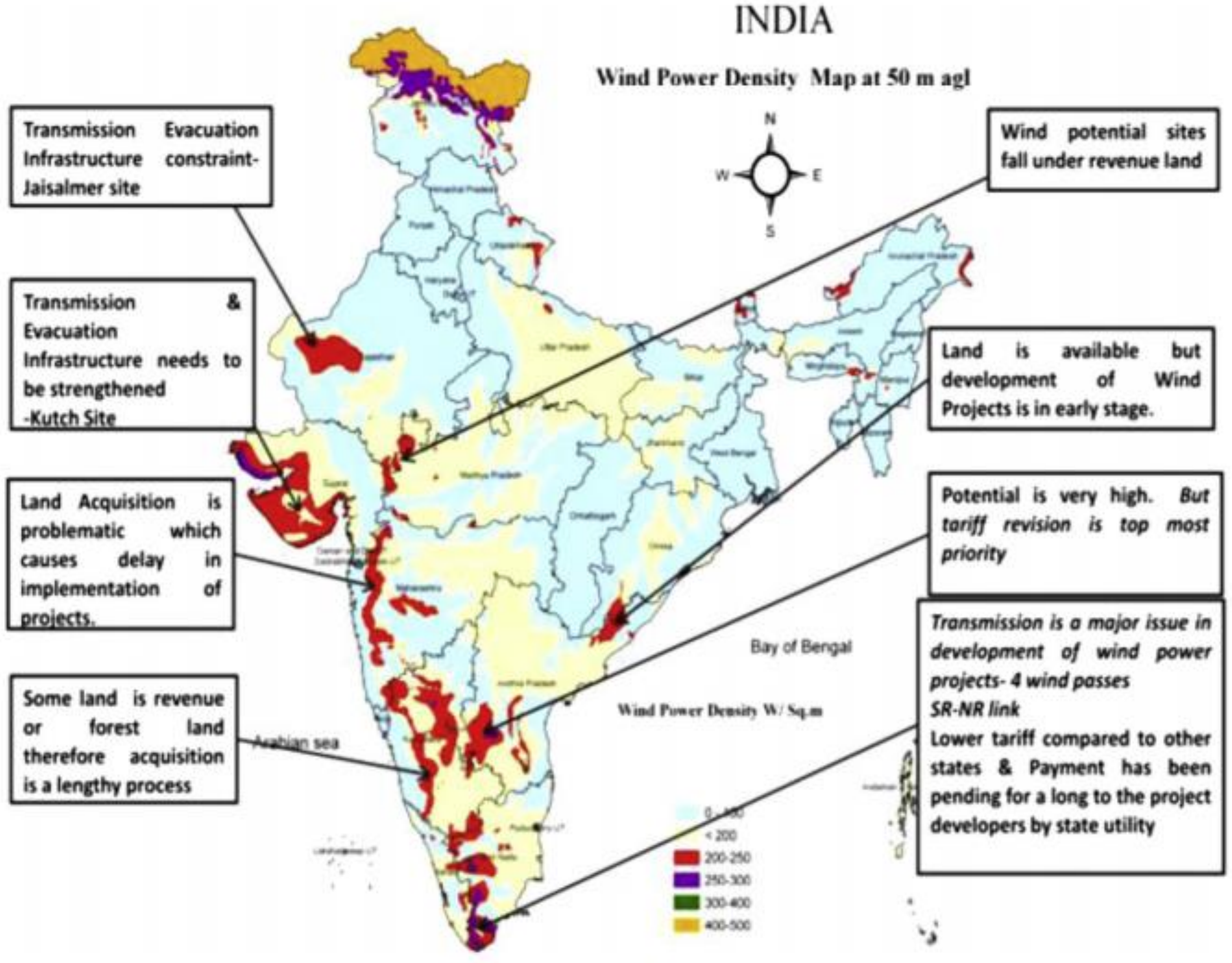


Fig. 12. Nation-wide immediate issues in harnessing wind potential.

Wind Power Plants (producing more than 50 MW)

Name	Location	State	Capacity (MW)
Muppandal windfarm	Kanyakumari	Tamil Nadu	1500
Jaisalmer Wind Park	Jaisalmer	Rajasthan	1064
Brahmanvel windfarm	Dhule	Maharashtra	528
Dhalgaon windfarm	Sangli	Maharashtra	278
Vankusawade Wind Park	Satara District	Maharashtra	259
Vaspet	Vaspet	Maharashtra	144
Mamatkheda Wind Park	Mamatkheda	Madhya Pradesh	100.5
Anantapur Wind Park	Nimbagallu	Andhra Pradesh	100
Damanjodi Wind Power Plant	Damanjodi	Odisha	99
Jath	Jath	Maharashtra	84
Welturi	Welturi	Maharashtra	75
Acciona Tuppadahalli	Chitradurga District	Karnataka	56.1
Dangiri Wind Farm	Jaiselmer	Rajasthan	54
Bercha Wind Park	Ratlam	Madhya Pradesh	50

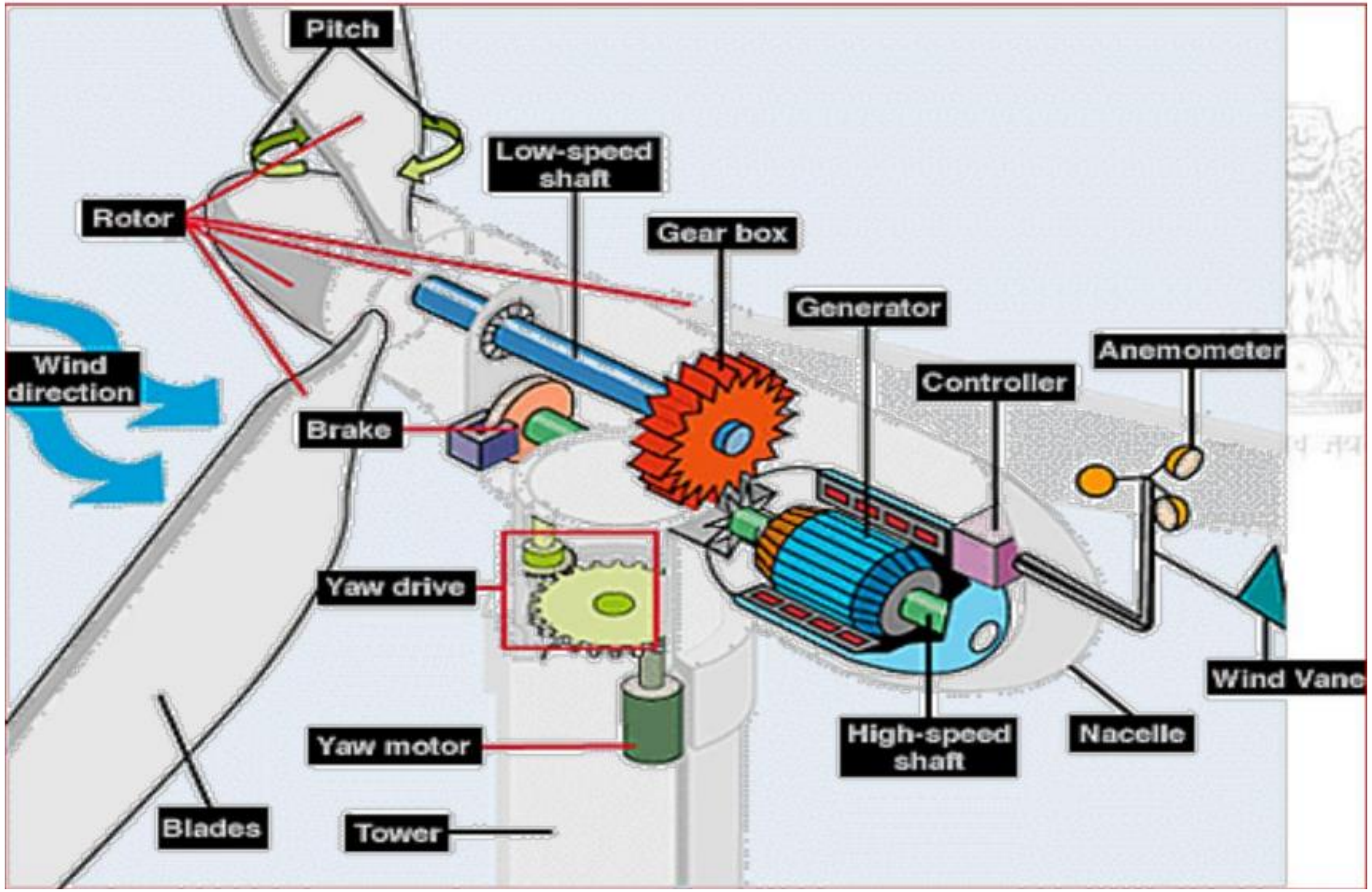
Wind Energy Conversion Systems

The wind energy conversion system (WECS) includes wind turbines, generators, control system, interconnection apparatus. Wind Turbines are mainly classified into horizontal axis wind turbines (HAWT) and vertical axis wind turbines (VAWT).

Modern wind turbines use HAWT with two or three blades and operate either downwind or upwind configuration. This HAWT can be designed for a constant speed application or for the variable speed operation. Among these two types variable speed wind turbine has high efficiency with reduced mechanical stress and less noise.

Variable speed turbines produce more power than constant speed type, comparatively, but it needs sophisticated power converters, control equipments to provide fixed frequency and constant power factor.

COMPONENTS OF WECS



COMPONENTS OF WECS

Anemometer-
Measures the wind speed

Blades-
Most turbines have 2 or 3. Wind blowing over the blades causes the blades to lift and rotate

Brake-
A disc brake can be used to stop the rotor in emergencies

Controller-
The controller starts up the machine at wind speeds of about 8 to 16 miles per hour (mph) and shuts off the machine at about 55 mph. Turbines do not operate at wind speeds above about 55 mph because they might be damaged by the high winds.

Gear box-
Gears connect the low-speed shaft to the high-speed shaft and increase the rotational speeds from about 30 to 60 rotations per minute (rpm) to about 1000 to 1800 rpm, the rotational speed required by most generators to produce electricity. The gear box is a costly (and heavy) part of the wind turbine and engineers are exploring "direct-drive" generators that operate at lower rotational speeds and don't need gear boxes.

COMPONENTS OF WECS

Generator-
Usually an off-the-shelf induction generator that produces 60-cycle AC electricity. Gear box

Low-speed shaft-
The rotor turns the low-speed shaft at about 30 to 60 rotations per minute.

Nacelle-
The nacelle sits atop the tower and contains the gear box, low- and high-speed shafts, generator, controller, and brake. Some nacelles are large enough for a helicopter to land on.

Pitch-
Blades are turned, or pitched, out of the wind to control the rotor speed and keep the rotor from turning in winds that are too high or too low to produce electricity.

Rotor-
The blades and the hub together are called the rotor.

Tower-
Towers are made from tubular steel (shown here), concrete, or steel lattice. Because wind speed increases with height, taller towers enable turbines to capture more energy and generate more electricity.

COMPONENTS OF WECS

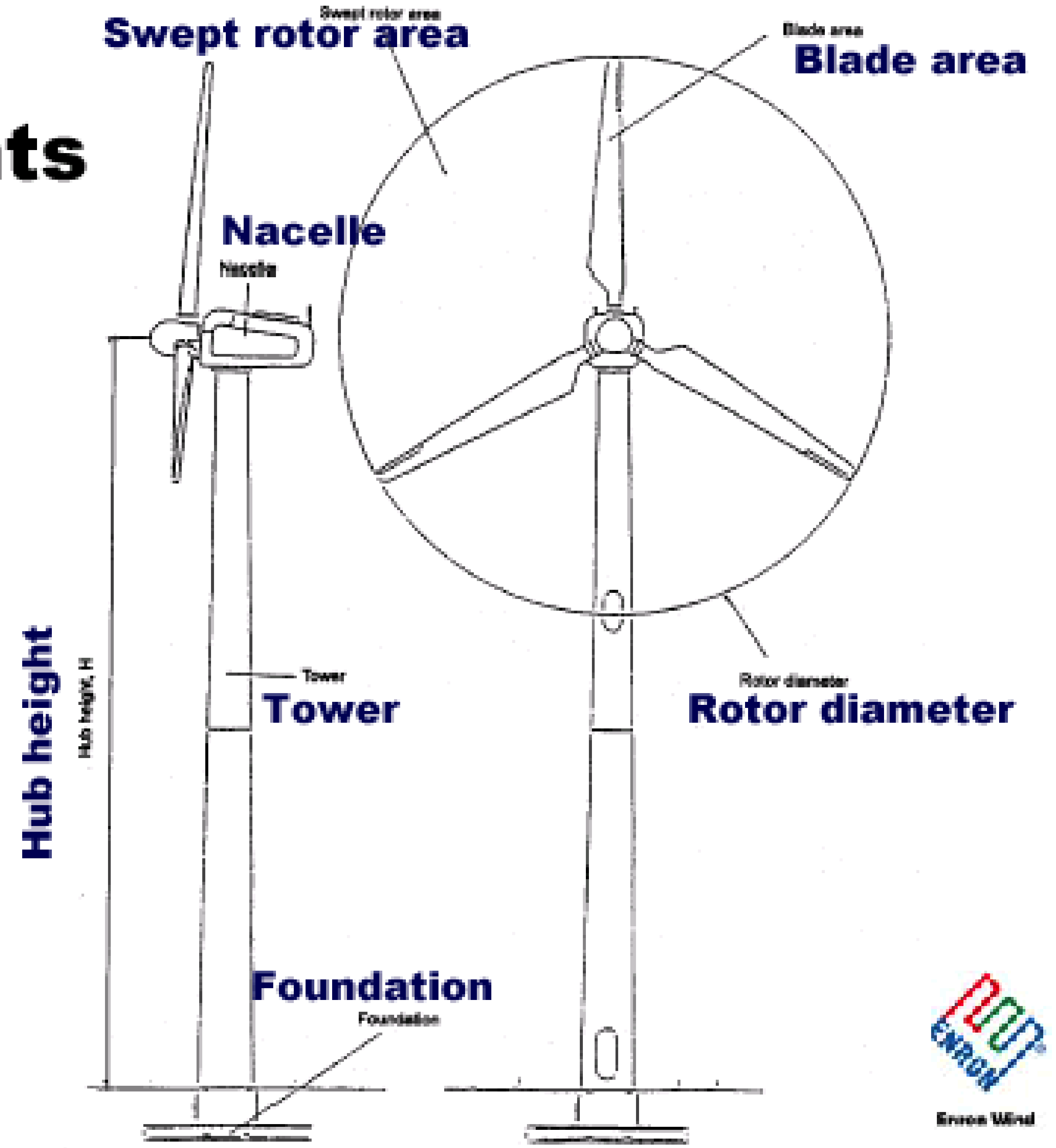
Wind direction-
This is an "upwind" turbine, so-called because it operates facing into the wind. Other turbines are designed to run "downwind," facing away from the wind

Wind vane-
Measures wind direction and communicates with the yaw drive to orient the turbine properly with respect to the wind.

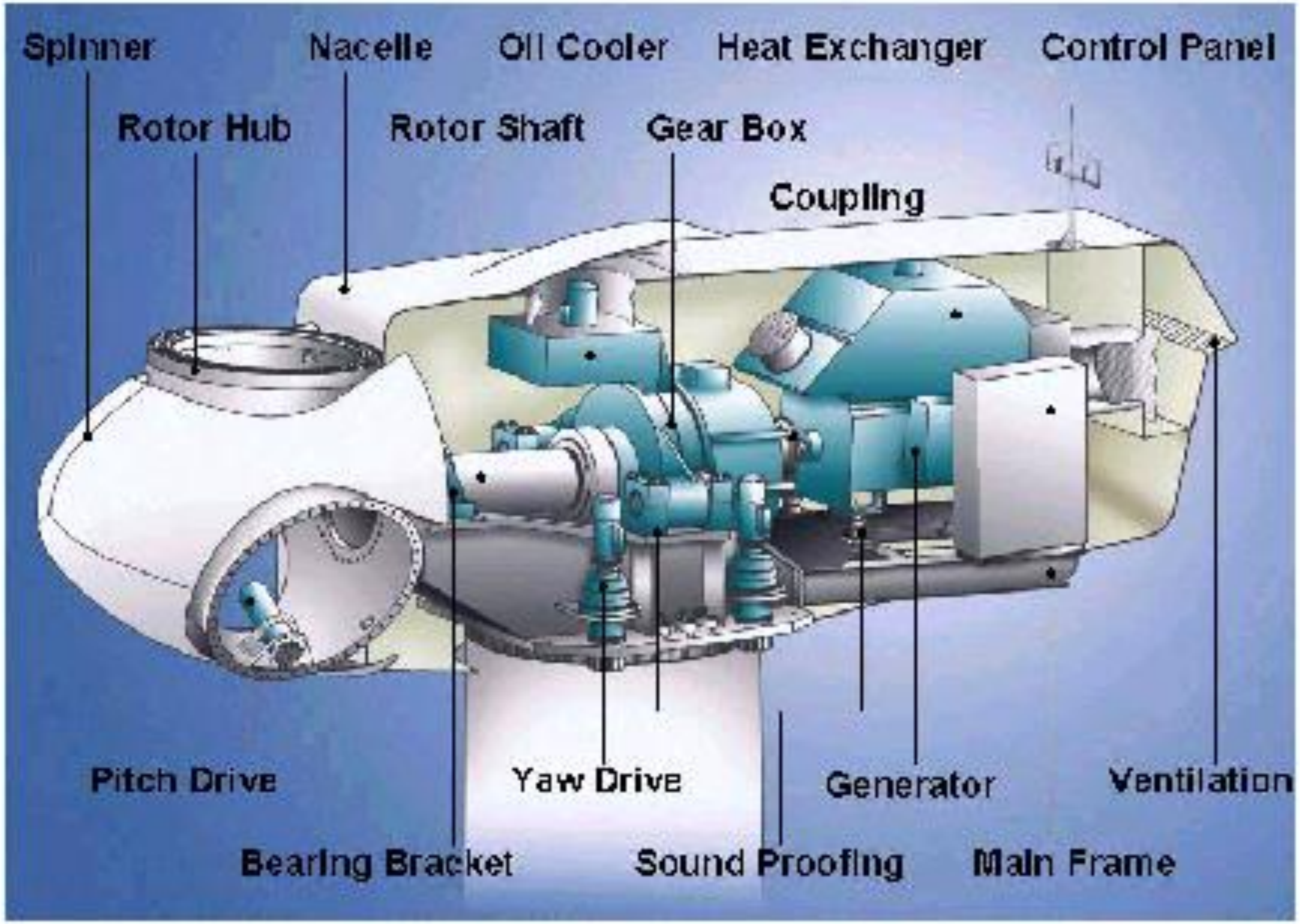
Yaw drive-
Upwind turbines face into the wind; the yaw drive is used to keep the rotor facing into the wind as the wind direction changes. Downwind turbines don't require a yaw drive, the wind blows the rotor downwind.

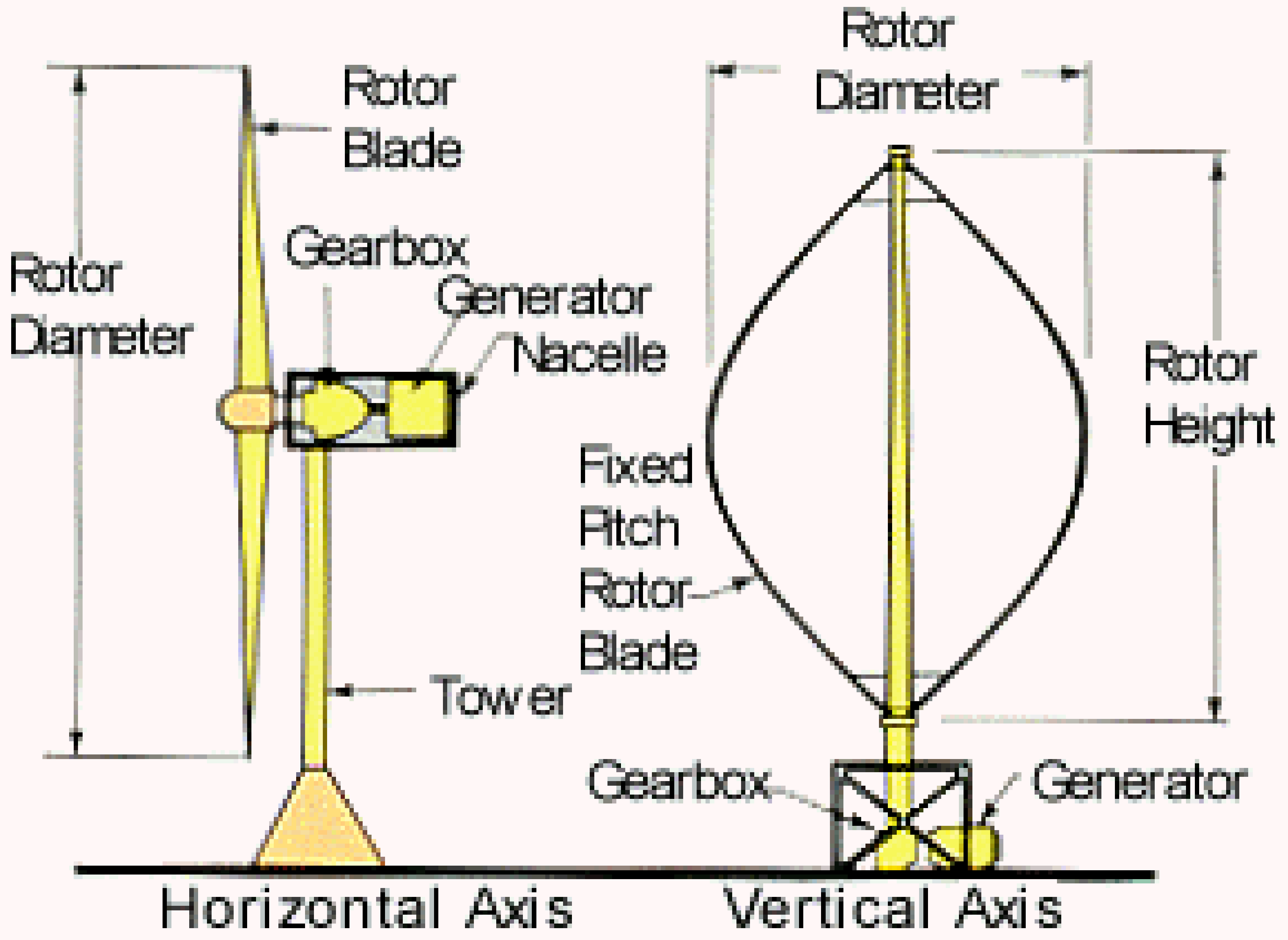
Yaw motor-
Powers the yaw drive.

Main Components of a wind turbine



Components - Turbine Layout





Wind Turbine Configurations

POWER OBTAINED FROM WIND

A wind turbine obtains its power input by converting the force of the wind into torque (turning force) acting on the rotor blades. The amount of energy which the wind transfers to the rotor depends on the density of the air, the rotor area, and the wind speed.

1 Density of air.

The kinetic energy of a moving body is proportional to its mass. The kinetic energy in the wind thus depends on the density of the air, i.e. its mass per unit of volume. In other words, the “heavier” the air, the more energy is received by the turbine. At normal atmospheric pressure and at 15◦C, the density of air is 1.225 kg/m3 , which increases to 1.293 kg/m3 at 0◦C and decreases to 1.164 kg/m3 at 30 ◦C. In addition to its dependence upon temperature, the density decreases slightly with increasing humidity. At high altitudes (in mountains), the air pressure is lower, and the air is less dense. It will be shown later in this chapter that energy proportionally changes with a variation in density of air.

POWER OBTAINED FROM WIND

2 Rotor area.

When a farmer tells how much land he is farming, he will usually state an area in terms of square meters or hectares or acres. With a wind turbine it is much the same story, though wind farming is done in a vertical area instead of a horizontal one. The area of the disc covered by the rotor (and wind speeds, of course), determines how much energy can be harvested over a year. A typical 1,000 kW wind turbine has a rotor diameter of 54 m, i.e. a rotor area of some 2,300 m2 . The rotor area determines how much energy a wind turbine is able to harvest from the wind. Since the rotor area increases with the square of the rotor diameter, a turbine which is twice as large will receive 2 2 , i.e. four times as much energy.

Rotor diameters may vary somewhat from the figures given above, because many manufacturers optimize their machines to local wind conditions: A larger generator, of course, requires more power (i.e. strong winds) to turn at all. So if one installs a wind turbine in a low wind area, annual output will actually be maximized by using a fairly small generator for a given rotor size (or a larger rotor size for a given generator). The reason why more output is available from a relatively smaller generator in a low wind area is that the turbine will be running more hours during the year.

POWER OBTAINED FROM WIND

3 Wind velocity.

Considering an area A (e.g. swept area of blades) and applying a wind velocity v, the change in volume with respect to the length "l" is:

$$V = A \cdot l, \qquad v = l / t \qquad \Rightarrow V = A \cdot v \cdot t.$$

The energy in the wind is in the form of kinetic energy. Kinetic energy is characterized by the equation:

$$E = ½\, mv^2$$

The change in energy is proportional to the change in mass, where

$$m = V \,.\, \rho a$$

and ρa the specific density of the air. Therefore, substituting for V and m yields

$$E=1/2*A*\rho a * v^3 * t$$

Energy Conversion in Wind

From the previous equation it can be seen that the energy in the wind is proportional to the cube of the wind speed, v^3 . The power P is defined as Therefore, power in wind is proportional to v^3 .

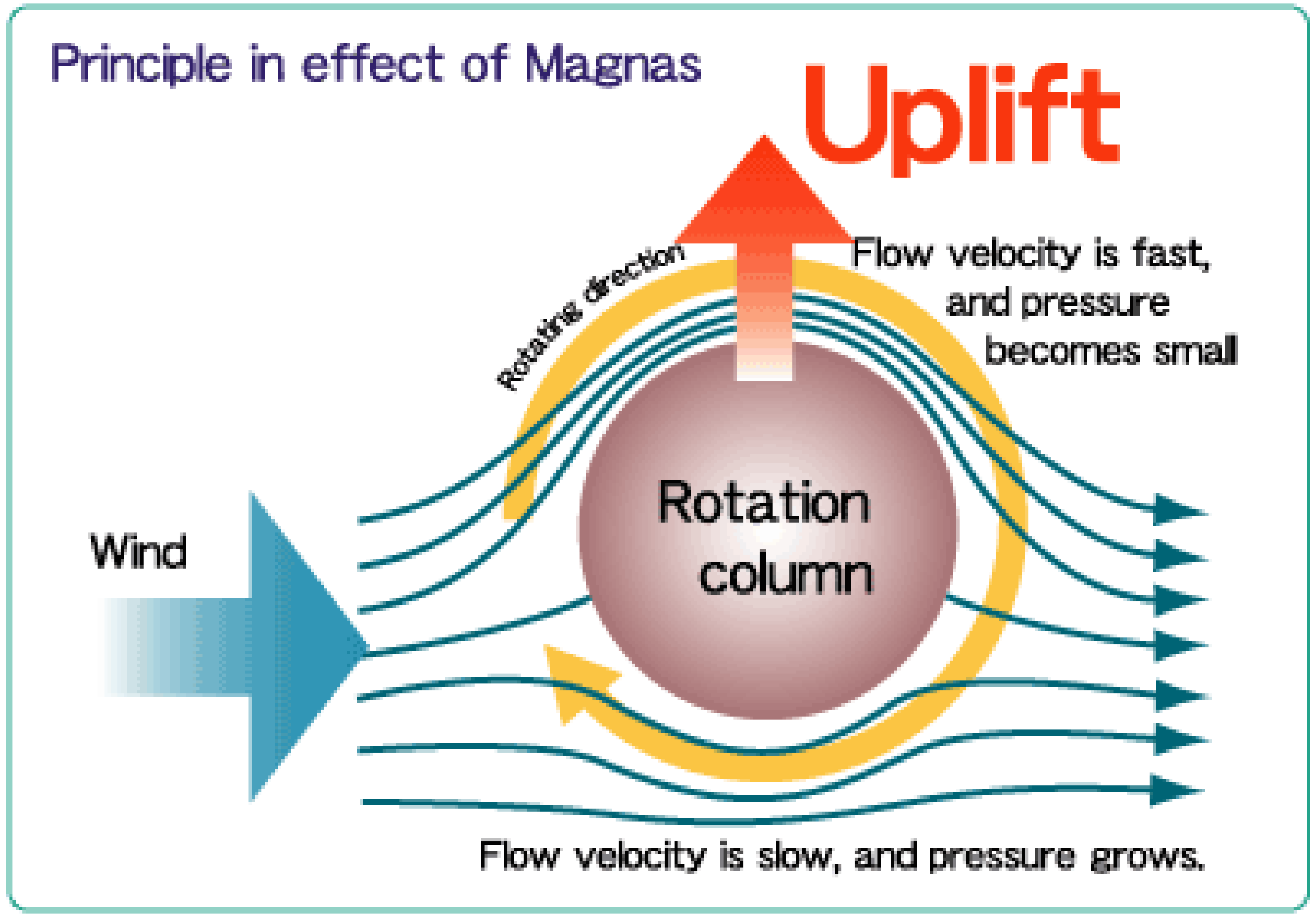
From Fig. it can be seen that the power output per m^2 of the rotor blade is not linearly proportional to the wind velocity, as proven in the theory above. This means that it is more profitable to place a wind energy converter in a location with occasional high winds than in a location where there is a constant low wind speed.

Measurements at different places show that the distribution of wind velocity over the year can be approximated by a Weibull-equation. This means that at least about 2/3 of the produced electricity will be earned by the upper third of wind velocity.

From a mechanical point of view, the power density range increases by one thousand for a variation of wind speed of factor 10, thus producing a construction limit problem. Therefore, wind energy converters are constructed to harness the power from wind speeds in the upper regions.

Principle of Magnus effect

Bernoulli's principle - the pressure is lower on the side where the velocity is greater, there is an unbalanced force - Magnus force.



Application

Small Turbines (<1kW)

- Homes(grid-connected)

-Farms

-Remote applications

Intermediate wind turbines(10-500kW)

-Village power

-Hybrid systems

-Distributed power

Large wind turbines (500kW -5MW)

-Central station wind farms

-Distributed power

-Off-shore wind

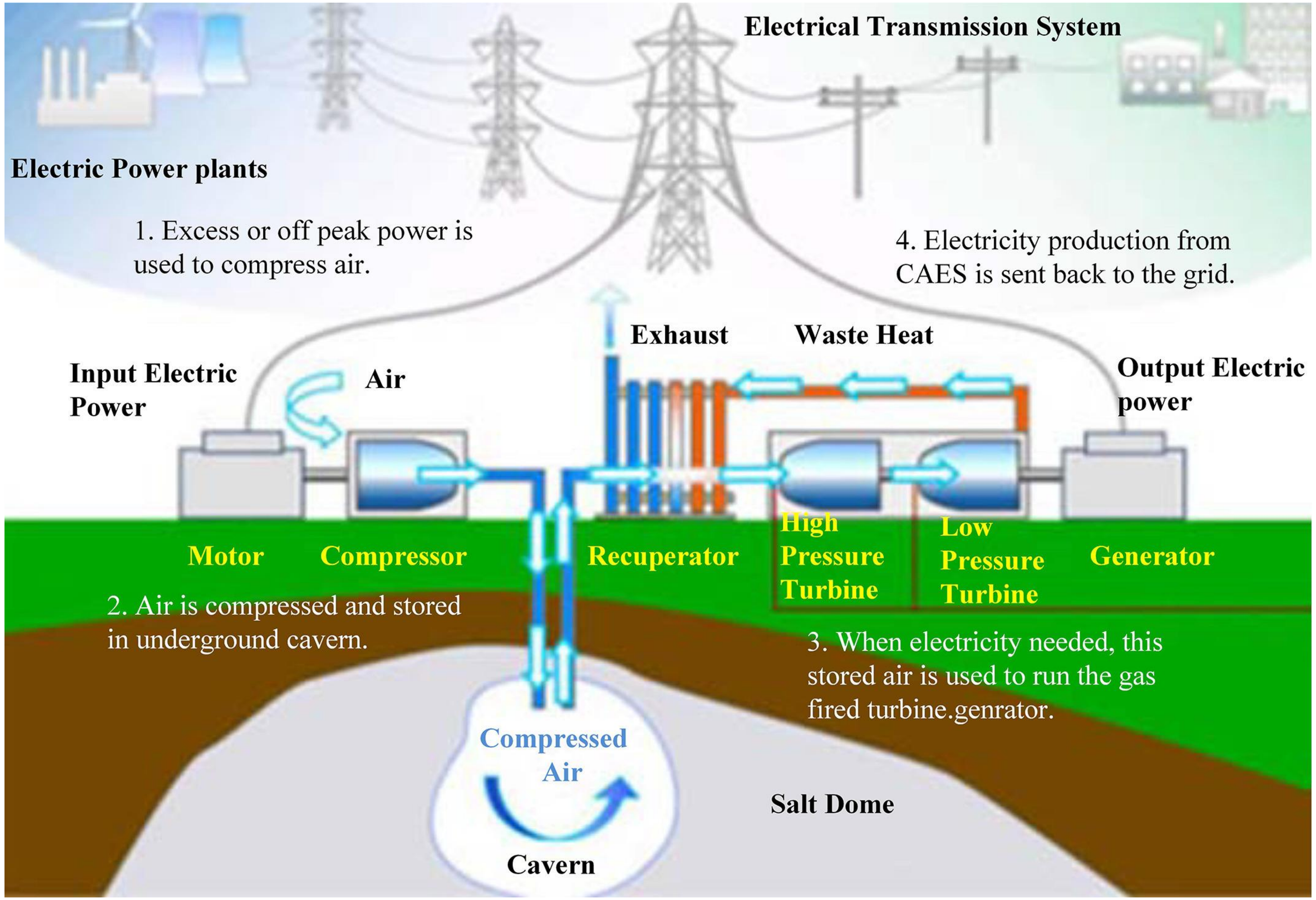
Advantages

- Very low carbon dioxide emissions (effectively zero once constructed).
- No air or water pollution.
- No environmental impacts from mining or drilling.
- Completely sustainable—unlike fossil fuels, wind will never run out.
- Turbines work almost anywhere in the world where it's reliably windy, unlike fossil-fuel deposits that are concentrated only in certain regions.
- Unlike fossil-fueled power, wind energy operating costs are predictable years in advance.
- Freedom from energy prices and political volatility of oil and gas supplies from other countries.
- New jobs in construction, operation, and manufacture of turbines.

Disadvantages

- High up-front cost .
- Extra cost and complexity of balancing variable wind power with other forms of power.
- Extra cost of upgrading the power grid and transmission lines, though the whole system often benefits.
- Damage local wildlife
- Large overall land take—though at least 95 percent of wind farm land can still be used for farming, and offshore turbines can be built at sea.
- Can't supply 100 percent of a country's power all year round, the way fossil fuels, nuclear, hydroelectric, and biomass power can.
- Loss of jobs for people working in mining and drilling.

Wind energy storage (CAES)



ENVIRONMENTAL ASPECTS

Wind power plant as a renewable energy source has slight influence on environment, nevertheless people reluctantly agree to construct power plants in their neighborhood.

Noise is one of the most common environmental aspect -
The noise has two sources: mechanical (inherent in the gearing system – excluding double feed system) and the second one related with aerodynamics of the rotor blade. The first one is possible to eliminate but the second one not. The aerodynamic noise arise when the rotating blade passing the tower. That effect calls the tower thumb. The most influence on the level of loud has wind speed. When the wind blow fast the background noise is enough loud to drown out the tower thumb effect but when the wind is blowing lightly the tower thumb effect is audible in long distance.

Electromagnetic interference-
Large structures like wind rotor and tower can cause objectionable electromagnetic interference in the performing of a nearby transmitters or receivers. Moreover the rotating blades can also reflect signals what make experience interference at the blade passage frequency. The highest influence on that effect strength has location. This problem is important for onshore technology but in some of case large offshore power plants the problem could be higher. The offshore power plant can interference with radar and flight paths to airfields.

ENVIRONMENTAL ASPECTS

Effect on birds-

The wind turbine blade is a lethal weapon against any avian population. The birds may be killed or at least injured if the collide with blade. The most often situation the suction draught created by wind flowing to a turbine caught the birds and poke them into air stream headed for the blades. Extremely dangerous are turbines with lattice towers, where the bird has possibility to nest. Therefore often wind farms have to be sited away avian flight paths.

Visual impact mainly for onshore wind farms-

The problem is related with property owners around the wind farm, who do not allow for wind power plant installation in their neighborhood. However that problem also regard offshore technology for farms installed near resorts.

New workplaces-

Usually it is a job for a local technicians and engineers. At present generally jobs are related with onshore technologies however offshore becoming more and more common.

Safety in Wind power plants

Falls:
Wind turbines vary in height, but can be over 100 feet tall. The height of these structures makes wind turbine safety a challenge. As most wind farms are exposed to high winds and all kinds of weather conditions, working at a height is made more dangerous. Workers on wind farms often have to climb ladders multiple times a day. This may result in workers falling if they do not have their harness on properly. In relation to regulations, construction workers on wind farms, when exposed to fall distances of 6 feet or more, must be protected from falls by using:

-Guardrail Systems

-Safety net Systems

-Personal fall arrest systems

Safety in Wind power plants

Cranes:
Cranes are used during the construction and maintenance of wind farms. Even when cranes are constructed correctly there can still be fatalities. Significant wind turbine safety issues to be considered when operating a crane include:

-Cranes should only to be operated by qualified workers with the right documents and training

-There should be routine inspections before and after each use to ensure wind turbine safety.

-Fully extend outriggers and barricade accessible areas inside the swing radius of the crane

-The crane should be situated on a stable surface

-Keep an eye out for overhead electric power lines and maintain at least a 10-foot working clearance from the lines

-Do not move loads over workers

Safety in Wind power plants

Confined Spaces:

The majority of wind farm workers work inside the wind turbine which is why ensuring wind turbine safety is so crucial. This is a small space with room for only one worker at a time. Some workers may not find working in a confined space to be a comfortable experience. They may suffer from claustrophobia or panic attacks which is intensified by the low oxygen levels in a turbine. You should ensure your worker is comfortable working in confined spaces and provide clear and simple exit routes.

First Aid –

It's vital that your workers are trained on first aid as many wind Farms are in remote areas which makes it difficult to reach a hospital quickly. In the event of an accident, you must have someone on site at all times who is fully trained in first aid. It's a good idea for all your workers to have at least some first aid training and they should all be aware of the location of the first aid box on site.

Hazardous Gases –

During the manufacturing of wind turbine blades workers may be exposed to harmful gases, vapors, and dust. These workers must be protected from these gases through good ventilation and the use of Protective Personal Equipment (PPE) such as respirators. Workers should know from their training which respirator to use and exactly where to get it on site. Good training is a crucial factor in high-quality wind turbine safety.

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Thank you!